

An Examination of Factors Related to Radiation Safety Practices of Interventional Radiologic Technologists in Ohio

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Chapter 1

Introduction and Problem Statement

Interventional radiography is a field defined by the use of fluoroscopy to capture images of many different body areas to perform a diagnostic or therapeutic procedure (Junsto, 2006). Interventional radiology uses a fluoroscopic tube and image intensifier mounted on a C-arm to allow the physician to utilize a wide variety of angles and positions to sufficiently visualize the organs, arteries and veins of interest (Bakalyar, 1997). As with any type of imaging modality that uses ionizing radiation, the ever-advancing field of interventional radiology can pose a significant risk of damage to the patient as well as the operator when proper radiation protection techniques are not followed. Patients who undergo some procedures, such as a cardiac catheterization or multi-vessel angiography, can be enduring radiation exposure times upwards of 30 to 60 minutes (Bakalyar, 1997). Many patients who undergo interventional procedures will have multiple interventional studies performed on them in their lifetime as well as undergoing other types of imaging procedures using ionizing radiation such as computed tomography (CT) or radiography. Therefore exposure to harmful radiation can quickly cumulate over a person's lifetime. Not only will the patient receive this exposure, but if proper radiation safety protocols are not followed, the staff of an interventional suite may also receive relatively high doses of radiation exposure that can cause lasting effects. Effects of radiation exposure can be immediate, such as skin erythema; or delayed, such as the development of a specific cancer (Junsto, 2006). Due to this, it is of the utmost importance that interventionalists and personnel in an interventional suite are aware of radiation protection techniques and comply with these guidelines to not only protect the patients, but also themselves.

Currently, there is limited research on personnel and patient radiation safety compliance, particularly in an interventional setting. Therefore, the purpose of this study is advance the understanding of the factors related to knowledge of and adherence to radiation safety practices in interventional radiology suites by technologists in the state of Ohio.

This study will seek to answer the following questions:

1. What is the frequency with which interventional technologists comply with radiation safety practices?
2. What is the relationship between the self-reported knowledge of radiation safety practices and the:
 - a. level of initial radiography education obtained;
 - b. years in professional practice; and
 - c. type of work site
3. What is the relationship between the self-reported compliance with radiation safety practices and the:
 - a. level of initial radiography education obtained;
 - b. years in professional practice; and
 - c. type of work site

Literature Review

Radiation Exposure for Common Interventional Procedures

A prospective research study conducted by Mercuti et al. (2011) examined the radiation dose received by patients during cardiac catheterization using radial versus femoral access. The study examined all patients who underwent a cardiac catheterization procedure at a tertiary cardiac center in Ontario, Canada during a 1.5 year period and a multilevel regression analysis was completed following the data collection. In total, 5,954 diagnostic cardiac catheterizations were performed. Sixteen separate cardiologists performed the cases and all procedures were performed on a Philips fluoroscopic device. Radiation exposure for each individual in this study was recorded as cumulative air kerma (AK) at the interventional reference point, measured in milligray (mGy). Computerized software was used to automatically record these values. The AK was then logarithmically transformed (LogAK) because the distribution was skewed positively. Other factors considered in this study were age, sex, body mass index (BMI), coronary artery bypass graft surgery (CABD), peripheral vascular disease (PVD), and the presence of a fellow in the case (Mercuti et al, 2011).

The study collected the data on 5,954 cases to determine the proportion of patients who underwent femoral access versus radial access then compared average radiation dose. The researchers found that they were unable to reject the null hypothesis that radial access and increased radiation dose to the patient during a cardiac catheterization will not significantly differ between operators. The research team found that intra-physician variance is greater than inter-physician variance. It was determined by this study that the average radiation dose for radial cases is higher than for femoral cases, which supported the hypothesis that radial artery access is associated with increased radiation exposure (Mercuti et al, 2011).

The primary concern of this study was to determine whether radiation dose per patient could be reduced if one access site was used over another. Not only would this technique reduce radiation dose to the patient but it would also decrease scatter radiation to the operator, a variable often overlooked by previous literature. The study demonstrated that although there was a higher average dose related to radial access, the dose received was still well below the 2-Gy threshold for deterministic effects. The researchers noted that although the radiation dose was higher for radial access versus femoral, the increase would only result in a marginal increase of risk for stochastic effects, especially considering the age of most patients utilizing this type of procedure (Mercuti et al, 2011). The appropriate access site is determined based on clinical indications and the patient's history for risk of complications. However, if the patient is likely to undergo multiple fluoroscopic procedures or other types of radiation exposure during his or her lifetime, considerations should be taken to reduce radiation dose. The research study suggested that if physicians opt to utilize radial access, proper use of beam restriction, shielding, and equipment safety should be used to reduce radiation exposure and the production of scatter radiation (Mercuti et al, 2011).

The research study presented by Mercuri et al (2011) had several limitations which should be considered. Primarily, the study was conducted at one tertiary cardiac care center in Ontario, which will reduce external validity. The research study should be replicated in multiple cardiac care centers in various locations to improve the generalizability of the findings. It is unclear how these results will translate into other procedures or centers. A randomized controlled trial could be used in future studies to investigate the problem more universally. It was not noted the distance of the x-ray tube to the entrance point of the patient, which could greatly increase or decrease patient dose. Data regarding operator dose (such as dosimeter readings) was not

available for access to the research team. It is also important to recognize that the initial reading, air kerma, was logarithmically transformed and should be analyzed with caution.

A prospective research study conducted by Glichrist et al. (2006) investigated transradial versus transfemoral approach to combined right- and left-heart catheterizations to determine complications and fluoroscopic time related to both types of access. Complications were defined as any arterial/venous (AV) fistula, pseudo aneurysm, or hematoma/hemorrhage that resulted in delayed hospital discharge. Procedure time was defined as the time when the sterile drapes were placed until the patient moved to a recovery area.

The study analyzed 475 patients with bilateral heart catheterizations performed by four separate operators and used 175 femoral/105 radial patients who met the study criteria. Procedural durations showed that times were shorter in the radial group with an average of 70 minutes versus 75 minutes for the femoral group. X-ray exposures were also shorter in the radial group versus the femoral group, with average times of 9.7 versus 12.6 minutes, respectively. Complications were recorded in 12 of the femoral cases and 0 of the radial cases (Gilchrist, 2006).

This prospective research study determined that if it is possible for physicians to use radial access over traditional femoral access, procedure time as well as x-radiation time can be reduced (Gilchrist, 2006). Another benefit of radial access demonstrated in this study was reduced complications and delayed hospital visit, which is not only beneficial to the patient but also to the hospital. Reduced x-radiation time translates into reduced patient dose as well as a reduction in the scatter radiation received by the operators. However, there are several limitations to this study. For one, it was conducted at one care center by only four separate physicians. The sample size of this study could also be of concern to generalizability. It is

unclear how this study would translate into other care centers and procedures. Furthermore, although x-radiation time was noted, there was no actual calculation of patient dose, so conclusions should be developed with extreme caution as radiation dose can vary by location of the x-ray tube, coning, and shielding (Gilchrist, 2006).

The previously described studies by Mercuri et al. and Gilchrist et al. both analyzed radiation dose as related to access sites for cardiac catheterization procedures. Both studies were prospective; however both studies were performed at only one cardiac care center suggesting that further research should be done employing multiple care centers and performing physicians. The research study performed by Mercuri et al. (2011) concluded that radiation dose measured by air kerma was significantly higher in radial access versus femoral access. The study performed by Gilchrist et al. (2006) determined that x-radiation time was significantly lower for radial access versus femoral access. The results for these studies is conflicting which leads to confusion for practitioners regarding which type of access should be used to reduce patient dose as well as operator dose received by scatter radiation. Neither study investigated the dose operators received during the procedures. This is an important factor to consider since physicians and technologists will be performing many of these procedures in their careers and steps should be taken to protect the professionals as well as the patients.

In a retrospective study performed by Raelson et al. (2009), the risk of children developing cancer after receiving diagnostic and therapeutic neuroangiography was investigated. The study's goal was to establish dose rates of radiation received, to determine the total radiation dose from all angiographic and computerized tomography (CT) studies the patient underwent during the study period, and to use this information to calculate the increased risk of developing cancer. The study included 68 patients between the ages of 0 and 17 at the Harborview Medical

Center between 2004 and 2008 who underwent neuroangiographic procedures. All radiation dose data was recorded during the procedures as the dose-area product (DAP), which is the product of the exposed field of view and the radiation dose measured in that area. The DAP was measured and recorded in Gray by centimeter-squared, or ($\text{Gy} \times \text{cm}^2$) and the effective dose and entrance skin dose (ESD) were calculated using conversion factors. Furthermore, the cumulative dose from all angiographic procedures was combined with the total dose from all CT studies to report a total radiation exposure value. Using the Biological Effects of Ionizing Radiation (BEIR) VII Report, the researchers computed the expected cancer risk from radiation exposure (Raelson et al, 2009).

The mean total DAP was $103.8 \text{ Gy} \times \text{cm}^2$ for a diagnostic procedure and $340.3 \text{ Gy} \times \text{cm}^2$ for a therapeutic procedure. This translated into an effective dose of 10.4 milliSievert, or mSv, for diagnostic and 34.0 mSv for therapeutic. This resulted into an ESD of 0.15 Gy for diagnostic and 0.58 Gy for therapeutic. There were no instances where the ESD values were recorded over the 2 Gy threshold for deterministic harm. The mean total DAP per patient was $280.5 \text{ Gy} \times \text{cm}^2$, equating to a mean ED of 28.1 mSv. The study recognized that CT scans accounted for an additional average of 35.3 mSv towards the effective dose, with the mean number of scans being reported as 9.6. When the angiographic procedures were combined with the CT studies, the total average effective dose was 63.3 mSv (Raelson et al, 2009).

Using the aforementioned data and the BEIR VII lifetime attributable risk of cancer estimates, the researchers concluded that the estimated excess cases of cancer in a population of 100,000 would be 266.6 for diagnostic procedures and 1,642.3 for therapeutic procedures. When radiation from CT studies was included, the number jumps to up to 1,913.6 excess cases. For males, the estimated risk of malignancy was 890.6 excess cases per 100,000 exposed children,

whereas the estimated risk of malignancy for females was 1,913.6 excess cases per 100,000 children exposed (Raelson et al, 2006).

This study demonstrated that the increase of excess risk of cancer hovers around 1% from the lifetime attributable risk of cancer in the population of exposed pediatrics. The data also indicated that the risk of cancer is nearly double for female children than for male children, however researchers did not note why and suggested that further research be done to investigate the differences in cancer risks between male and female children who undergo angiographic procedures. There are few limitations to this study. Primarily, the data underwent several conversions, so some precision could be lost during the mathematical manipulations. Secondly, the BEIR VII report determines the increased risk of cancer by using data from Japanese radiation accidents, so there is some uncertainty from the application of Japanese data to the American population. The BEIR VII report used data from atomic bomb survivors who were exposed to multiple types of radiation, not simply x-radiation. The main concern of the researchers in this study is for healthcare professionals to weigh the benefits of minimally invasive interventional neuroradiology with the damaging effects of excess radiation, especially in pediatric patients (Raelson et al, 2009).

Swoboda et al. (2005) investigated the amount of radiation received by pediatric patients who underwent diagnostic and interventional neuroradiology procedures and compared these doses with the thresholds for deterministic effects and doses received by adults, as well as the differences between interventional and diagnostic procedures. To measure the radiation dose, an automated patient dosimeter was placed on the lateral and frontal planes of the biplane neuroangiographic unit, which had fluoroscopic and digital subtraction angiography DSA, capabilities. The dosimeter had capabilities of measuring angiographic frames and total

fluoroscopic time during the procedure. The retrospective study included 100 pediatric patients ranging from age 1 week to 18 years at a tertiary pediatric hospital. Of the 100 patients, 76 underwent diagnostic procedures and 24 underwent interventional procedures. A diagnostic procedure was defined as one that used angiography to map out the vascular system and/or identify the problem to make a diagnosis. Contrary to this, an interventional procedure was defined as those in which any intervention was performed, including but not limited to coiling, embolization, or gluing. PEMNET, a type of dose measurement software, was used to correlate the radiation delivered at any given point by relating technique factors such as voltage and current with patient location, weight, and catheterization time. PEMNET utilizes the inverse square law to calculate entrance skin exposure to the patient. The computer software has been compared with ionization chambers and the calculated exposure values were within 7% of the actual doses delivered (Swoboda et al, 2005).

The results showed that frontal and lateral planes were used during both interventional and diagnostic procedures; however, the interventional modality employed use of the lateral plane much more than the diagnostic modality. Both diagnostic and interventional had higher entrance doses in the frontal plane than the lateral plane. The frontal plane showed an average of 25.7 milliGray, or mGy, whereas the lateral plane showed an average value of 11.3 mGy during fluoroscopic procedures. When DSA was employed, the average doses were 204.6 mGy for the frontal plane and 105.1 mGy for the lateral plane. Based on results from the study, the surface dose was more than twice as large for interventional procedures as for diagnostic procedures in the frontal plane; there was a mean fluoroscopic entrance dose of 53.3 mGy for diagnostic and 123 mGy for therapeutic procedures. This relationship increased even more in the lateral plane where the dose rate is 7.5 times higher for interventional procedures compared to diagnostic;

15.7 mGy for diagnostic versus 117 for therapeutic procedures. No association was found between entrance dose and age, which contradicts the thought that lower doses would be used for infants because of their measurably smaller size. There were also no correlations between catheterization time, patient age, or patient weight as related to skin entrance dose. During the study, no patient exceeded radiation dose of 2 Gy; the maximum dose was recorded as 1.6 Gy. The first signs of deterministic effects due to radiation occur at the threshold of 2 Gy. Since this threshold was not reached, no immediate negative effects were seen (Swoboda et al, 2005).

There are multiple details to consider when analyzing this research study. To begin, the study was done in retrospect due to the lack of research and literature in pediatric interventional radiology dose measurements. Because the study was done in retrospect, the first signs of skin erythema were not able to be documented since the symptoms, fading after 48 hours, are comparable to sunburn. Due the technical error of 7% of the PEMNET computer measurement software, one should recognize that actual dose rates could vary slightly from those recorded. Furthermore, the study assumed that the radiation was only received by one area and did not deviate from that area. Since fluoroscopy is often used in real-time and frequently moved throughout any set procedure, it is unlikely that the entire radiation dose was focused on one area. This resulted in the recorded entrance dose being the maximum dose received, whereas it is much more likely that not one particular area received that given amount of radiation (Swoboda, 2005).

A study conducted by Theiry-Chef, Simon, and Miller (2006) investigated the increased risk of cancer among pediatric patients who underwent cerebral embolization during an interventional neuroradiology procedure. The study assessed skin dosage resulting from the radiation used in surgery to embolize intracranial aneurysms, arteriovenous malformations, or

tumors. The average entrance-peak skin dose and the age of the patient were used to calculate the increased lifetime risk of developing malignant brain tumors. The study included 50 patients from age 0 to 18 who underwent a procedure between the years 1998 and 2001 in seven different medical facilities in the United States. The radiation dose to the brain was not recorded during the procedures, so a mathematical model was utilized to calculate the amount of absorbed energy from the x-ray tube. The mathematical model, as developed by the Medical Internal Radiation Dose Committee, uses the factors of size, composition, and density of the brain as related to the age of the patients, the entrance dose, and characteristics of the radiation to determine the radiation dose absorbed by each 1 cm³ layer of the brain tissue. To determine the entrance dose, the researchers noted that exposure fields were not static but instead moved in real-time to track the catheter inside the brain. As a result, multiple field sizes and orientations were simulated to determine the patient-specific amount of radiation received relating to each procedure. A phantom brain was created to mimic each pediatric case and the average absorbed dose was determined from the dose received within all of the volumes of brain tissue. Following the calculation of absorbed dose, the remainder of a normal lifespan was estimated using the Interactive RadioEpidemiological Program (IREP) developed by the National Cancer Institute. The IREP model estimates the probability of developing cancer due to radiation exposure (Thierry-Chef, Simon, & Miller, 2006).

The results of this study confirmed that there is an increase in cancer risk due to interventional neuroradiology by up to 80% from the baseline cancer risk for the pediatric population based on calculated risk related to dose received. The highest amounts of radiation doses were recorded where the lateral and frontal examination fields overlapped during the procedure. It was noted that the infant patient received a high score of 0.7 for each unit peak skin

dose whereas the adolescent patient received a high score of 0.4 for each unit peak skin dose. The lower score was concluded to be due to the thicker cranium of an adolescent. Additionally, the researchers also determined that when the radiologists used proper collimation techniques, the average dose could be reduced by up to 95% for the adolescent patient and 70% for the infant patient. The risk of cancer was increased 2% to 10% in the patient who received the lowest dose. The rate of cancer was estimated to increase from the baseline of 65 cases of brain cancer per 10,000 to 66 or 71, dependant on the actual conditions of the exposure. For the patient who received the highest dose, the risk of cancer ranged between a 10% and 80% increase. In effect, for every 10,000 exposed children, the number of expected number of cases of brain cancer would increase from 65 to 71-117, again dependant on the actual conditions of the procedure (Thierry-Chef, Simon, & Miller, 2006).

There are several limitations to this research study. Since actual radiation doses were not recorded in the brain during the original procedures, mathematical models were used to determine the amount of dose received. As with any mathematical model, there could be error and the actual amount of radiation used remains unknown for any given procedure. The sample size of patients was 50 cases, which is typically not large enough to form conclusions; however, it represents the largest set of data available for such procedures. This research study was conducted using applicable models set forth by international and national radiation and cancer committees, suggesting validity (Thierry-Chef, Simon, & Miller, 2006).

Interventional Personnel Radiation Exposure

A prospective research study was completed at the Academic Medical Centre in Amsterdam by Kuipers et al. to determine whether there was a linear relationship between radiation doses measured by two dosimeters worn above and below a .5 mm thick lead

equivalent apron by radiologists performing interventional procedures (2008). The study also looked at whether there was an increase in information gained from wearing two dosimeters versus only one. Eight radiologists were involved in the study that completed interventional fluoroscopically guided procedures. Personal dosimeters were worn above and below the lead apron at the level of the breasts. The two dosimeters were replaced every four weeks on the same day, and the study spanned 39 periods of 4 weeks each for 3 consecutive years. All studies were completed on the same equipment at the AMC and the data collected was analyzed using computer software. For statistical analysis, the doses under the lead apron were entered as dependent variables and the doses above the lead apron and the eight radiologists were considered dependent variables (Kuipers, 2008).

A total of 392 dosimeters were collected for analysis. Above the lead apron, the doses ranged from <0.01 to 16.78 mSv and under the lead apron the doses ranged from <0.01 to 0.83 mSv. Any dose measured under 0.01 mSv was entered as “0 mSv” for statistical analysis. The doses received by the radiologists did not differ significantly ($p > .05$) and the variance from under and over the lead apron did not differ significantly ($p > .05$). The average dose of the radiologists was 3.85 mSv in a four week period above the lead apron and 0.13 mSv in the same four week period under the apron. The statistical analysis of the data established a linear relationship between the doses above and those under the lead apron ($p < 0.05$, $R^2=0.59$) (Kuipers, 2008).

From this study, the researchers found that the interventionalist with the highest dose readings above and below the lead apron was mainly performing interventional procedures in patients with liver disease. The linear regression from this study, $Y = 0.036x - 0.004$, determined that the slope of the line (0.036) represented a 3.6% transmission of radiation through the lead

aprons. The present study determined that additional monitoring under the lead apron is not necessary to estimate the occupational exposure more accurately (Kuipers, 2008).

The study performed by Kuipers et al.(2008) was carried out to ensure that radiation exposure monitoring was accurate in interventional suites. The importance of occupational exposure monitoring stems from the idea that radiologists and personnel in an interventional suite will incur more harmful radiation side effects than the patients will if proper radiation safety protocols are not followed and the members of the staff entertain long careers. Although this study concluded that the use of 2 personal dosimeters must not be worn, it is crucial that personnel wear dosimeters and collect and report these dosimeters in a timely manner to monitor the amount of radiation dose received, and if necessary to reduce workload if ratings are too high.

Molyvda-Athanasopoulou et al. (2011) performed a prospective research study to analyze occupational radiation doses in fluoroscopy-guided diagnostic and interventional procedures. The study looked at three different categories and recorded patient and staff dose to determine whether further protection measures were necessary. The study included 32 patients who attended the AHEPA General Hospital for angiographic or angioplastic procedures. All procedures were performed on a Siemens C-arm Multistar angiographic unit, equipped with a flat ionization chamber for dose area product (DAP) measurements. Two doctors were always present in the room, both wearing .5 mm lead equivalent aprons and thyroid protective collars. Dosimeters were worn above the apron at the level of the collar and underneath the lead apron to assess entrance skin dose. To measure radiation dose to the patient, in addition to DAP, dosimeters were placed at the level of the thyroid gland and above the eyes to mainly measure scatter radiation. Dosimetric data was collected during 26 angiographies and 6 angioplasties

performed by four radiologists. Other data collected included kilovolt peak (kVp), milliampereseconds (mAs), field size, total DAP to the patient, and fluoroscopic times (Molyvda-Athanasopoulou, 2011).

For the estimation of the effective dose (ED), the absorbed doses were multiplied by tissue weighting factors published by the International Council on Radiation Protection (ICRP). The effective dose of the radiologists was found to correlate with the total DAP received by the patient. The correlation coefficients for angiography and angioplasty were 0.946 and 0.879, respectively. The effective dose of the assistant radiologist was found to be slightly smaller than the dose to the lead radiologist. The mean effective doses to radiologists were 11.6 and 10.1 microsieverts for angiography and angioplasty, while the mean effective doses to the assistant radiologist were 7.8 and 6.9 microsieverts. The contribution of fluoroscopic time to total procedure time also correlated with total effective dose to both the patient and the radiologist. Procedures centered around the abdominal aorta had the highest total DAP, followed by procedures of the aortic arch/carotid, and finally the lower limb. This was rationed by the research team as being due to complexity of the procedure and more critical organs becoming irradiated during the procedure (Molyvda-Athanasopoulou, 2011).

The research team found that nearly all occupational doses could be attributed to scattered radiation. The effective dose of the staff varied in procedure as related to the exposure parameters, the complexity of the procedure, and the expertise of the performing physician. When a radiologist was standing closer to the patient and therefore the path of the radiation, effective dose was found to be higher. In all procedures and measurements, however, the patient dose never surpassed the limit of 2 Gy, which is the threshold for skin erythema (Molyvda-Athanasopoulou, 2011).

Chida et al. examined the sources of staff-received scattered radiation in interventional procedures and outlined ways to reduce staff dose (2011). The researchers acknowledged the harmful risk of scattered radiation, particularly to the staff working in an interventional suite, and sought to alert the medical community of the risks associated with exposure to ionizing radiation. Sources of scattered radiation were visualized using a pinhole camera with image receptors. A 2-mm lead shield surrounded the camera except at the pinhole to control for excess radiation and to standardize the results. Two types of image receptors were used: an imaging plate [IP] and a single emulsion radiographic film. The film was used to detect visual images of the radiographic equipment, and the IP was used to detect staff-received scattered radiation, because it had much higher sensitivity than the film. To receive results, the film and the IP were combined to identify the locations and the sources of staff-received scattered radiation. The pinhole camera was placed where the theoretical central beam would enter the phantom. The fluoroscopic device then made exposures to the phantom. The following technical factors were used: tube voltage, 70 kV; duration time, 20 seconds; and digital cineangiography, 15 f/s (Chida 2011).

The research team found that scattered radiation that reached the staff likely came from two sources: the patient or phantom and the support table; and the cover or exit port of the x-ray beam collimating device. The concerning factor found by the research team was the amount of scattered radiation leaving the x-ray collimating device. The cover of the beam is traditionally very small and made of thin acrylic. The percentage of attenuation is very small, and the distance between the cover of the beam collimating device and the x-ray source is also very small, so the intensity of scattered radiation at this point is very high. Little is known about this effect. The study found that significant collimation is useful in reducing patient dose, and therefore also staff dose. The research team suggested that physicians and staff follow the inverse square law to

reduce staff dose. The physician is typically the staff member closest to the x-ray beam and therefore to the scattered radiation, so any movement away from the beam would significantly reduce dose (Chida 2011).

The research conducted by Chida et al (2011) provided useful information to the interventional community about the sources of scattered radiation, which is what has the greatest influence on staff effective dose. With the knowledge presented by the research team, staff members can be educated about the sources of the highest amount of scattered radiation and therefore make conscious efforts to reduce their own exposure. This study was completed only once, however, so the reliability and reproducibility of the pinhole camera should be investigated further to determine the accuracy of the measurements. Although it is only preliminary information, it should still be taken heavily by professionals working in an interventional suite to protect themselves from the dangerous effects of scattered radiation.

Personnel Radiation Protection Practices

Slechta and Raegen (2008) attempted to examine factors related to radiation protection among technologists in the United States by means of a 32-item questionnaire. The questionnaire was mailed to a random sample of 2000 certified radiologic technologists in 2003 and a return rate of 23.9% yielded 454 questionnaires to be analyzed. The objective of the survey was to advance understanding of factors related to knowledge and adherence to radiation safety practices. The study investigated 4 independent variables (type of initial professional education, participation in continuing education, years in professional practice, and type of work site) and 2 dependent variables (knowledge of and compliance with radiation safety practices). The assumptions of the survey were that participation in the survey would give an accurate portrayal of radiation safety practices, any bias would result in underestimates rather than overestimates,

the questionnaire was valid, and the prediction of relationships between variables are reasonable based on previous studies. The survey was mailed to 2000 technologists with an estimate of a 15% return rate, resulting in 300 responses and a 95% confidence level with a 6% margin of error.

The questionnaire included 32 questions along with questions relating to demographic information and the four independent variables. The survey was divided into 10 questions about characteristics of the respondents, 19 questions regarding compliance with safety practices, and 3 questions regarding knowledge of safety practices. A pretest was given to 40 radiologic technologists at 3 clinical sites to determine whether self-reporting would give an accurate idea of radiation safety practices. Once mailed, there were 475 returned questionnaires (Slechta & Raegen, 2008).

The study found that the average time of professional practice was 15.84 years, and most participants had worked in hospitals (65%). The most common type of initial professional education was a two-year degree (45.4%) followed by a hospital based program (41.6%). almost all of the respondents (98.9%) had participated in at least one continuing education program within the year. The characteristics of the survey respondents were comparable to the characteristics of registrants of the ARRT in 2004. The mean composite score for knowledge was 82.2% and the mean composite score for compliance was 72.2%. Both variables were skewed to the right. The only independent variable found to be significantly correlated to the composite score knowledge was initial education ($P < .05$). For compliance practice scores, significant correlations were found for years in practice and work site ($p < .05$) (Slechta & Raegen, 2008).

Slechta and Raegen (2008) determined that there was poor compliance with radiation safety practices, especially safety practices that were in place to reduce unnecessary exposure to personnel. The data indicated that higher levels of compliance in larger sites. The survey was unable to describe why certain associations were found between variables. Additional study was recommended by the researchers to better understand the relationships between variables. Further study of this issue will help organizations understand what needs to be done to better the professional practice of their employees to reduce radiation exposure to patients as well as technologists.

Raegan and Slechta (2010) conducted a second study to determine radiation safety practices among California radiologic technologists certified by the American Registry of Radiologic Technologists. The objectives of the study were to determine whether key findings of the national study (Slechta & Raegen, 2008) could be replicated with a revised questionnaire and with the California population, and to determine whether there was a significant difference between compliance with personnel safety practices and patient safety practices. The survey looked at the independent variables of initial education, highest level of education, years of professional practice and type of work site. The new survey assumed that any bias would result in an overestimate of safety compliance. The survey used was a refined version of the survey used in the national study. The survey was mailed to 1500 technologists and resulted in 431 returned questionnaires usable for analysis. The questionnaire contained 32 items, including questions regarding demographic information, information on the independent variables, and information on compliance with personnel and patient safety practices. The scoring guidelines were developed to calculate the scores with safety practices and allowed for a high score of 22 for personnel safety and 37 for patient safety (Raegan & Slechta, 2010).

The questionnaire determined that the most common type of education was an associate's degree (61.7%) and a majority of technologists had been practicing for 16 or more years (46.1%). The most common place of employment was a hospital (64%). The study found that respondents who complied with patient safety practices were only slightly more likely to comply with personnel safety practices. The mean score for personnel safety practice was 70.5% and 77.1% for patient safety practice. A weak, positive correlation was found between primary work site and personnel safety ($r=.114$, $P<.05$), whereas a weak, negative relationship was found between years in practice and personnel safety practices ($r=-.100$, $P<.05$). No other relationships were found between the independent variables and compliance. For California, the best scores in compliance came from outpatient facilities, which contrast the conclusion from the national study that determined the hospitals had the best compliance scores (Raegan & Slechta, 2010).

The study supported the prediction that higher scores would be recorded for patient safety versus personnel safety. The researchers suggested that further research be done to address the question of how continuing education can improve radiation safety practices, why patient safety compliance is higher than personnel compliance when the staff could have more exposure to radiation than the patients, and what can be done to improve compliance with safety practices.

Sanchez et al. (2012) evaluated radiation doses recorded by personal dosimeters worn by interventional radiologists in 10 hospitals in Spain and correlated the measurements with the results of a questionnaire to analyze how occupational habits affect doses received. Measurements were recorded using thermoluminescent dosimeters worn above and below lead aprons. All participants wore 0.35 mm lead-equivalent protective aprons and a thyroid collar. Any interventionalist who reported wearing his or her dosimeter less than 7 days out of the month, as well as any dosimeter that reported as 0 mSv (background level), were removed from

the data set due to being considered abnormal. The questionnaire offered to the interventionalists included questions regarding workload and irradiation protection strategies. Data collected was analyzed using SPSS software.

A total of 28 radiologists were included in this survey. The average number of procedures per month was 50 +/- 16. A total of 36% of the radiologists reported that they forget to wear their dosimeter 7 or more days per month, and nearly half did not regularly use hand dosimeters. Interestingly, most of the participants reported that they do not have access to an over-apron dosimeter as recommended by the International Council on Radiation Protection (ICRP). All interventionalists reported that they stand at least 4 meters from the patient during at least 80% of digitally subtracted angiography (DSA) acquisition. Almost a third of the radiologists reported that they use a ceiling-suspended screen (CSS) in more than 80% of cases. Statistics showed that under-apron dose readings were reduced by 0.22 mSv for radiologists who used CSS, and performed 40 or less cases per month.

The survey completed by Sanchez et al. concluded that despite recommendations by national and international radiation protection agencies, some interventional radiologists continue to have poor radiation safety habits. The survey noted that nearly a third of radiologists surveyed, more than 30% do not use either a under- or over-apron chest dosimeters. Most participants did not have access to eye lens dosimeters despite the increase in concern over possible stochastic effects to the lens of the eye due to radiation exposure. There was no correlation observed between workload and average monthly readings, which suggested that it is possible to receive minimal doses even with a high number of procedures per month with good radiation protection habits. The lack of correlation here also suggested that despite a low number

of procedures, high doses are still able to be recorded if interventionalists have poor compliance with radiation protection rules.

Objectives and Research Questions

The objective of this study is to advance the understanding of the factors related to knowledge of and adherence to radiation safety practices in interventional radiology suites by technologists in the state of Ohio. This study investigates the relationship between 3 independent variables (type of initial professional education, years in professional practice, and type of work site) and 2 dependent constructs (knowledge of radiation safety practices and compliance with radiation safety practices). This study will seek to answer the following questions:

1. What is the frequency with which interventional technologists comply with radiation safety practices?
2. What is the relationship between the self-reported knowledge of radiation safety practices and the:
 - a. level of initial radiography education obtained;
 - b. years in professional practice; and
 - c. type of work site
3. What is the relationship between the self-reported compliance with radiation safety practices and the:
 - a. level of initial radiography education obtained;
 - b. years in professional practice; and
 - c. type of work site

Chapter 2

Research Design

This descriptive research study is a replication of the study conducted by Raegen and Selechta (2010). A web based survey (Survey Monkey) was used to survey interventional radiologic technologists regarding their education, years in practice, work site, knowledge of radiation safety practices and compliance with radiation safety practices. The questions are included in Appendix B. This research was considered exempt by The Ohio State University Internal Review Board. This study provides a descriptive analysis of the status of self-reported knowledge of and compliance with radiation safety practices of interventional technologists within the state of Ohio. It also explores possible relationships between the three independent variables and 2 dependent constructs.

Instrumentation

The electronic questionnaire was adapted to vascular interventional imaging from the paper instrument used by Raegen and Selchta (2010) and was scored in the same manner as the original survey (Appendix A). It is comprised the 38 questions as follows: 12 questions regarding characteristics of the respondents (Questions 1-7 & 34-38), 22 questions regarding compliance with safety practices (Questions 11-32), and 4 questions regarding knowledge of safety practices (Questions 8-10 & 33). The content and face validity of the original survey instrument was established by a 40 panel expert (Raegen & Selchta, 2010). The content and face validity of the revised survey instrument was assessed by a panel of four experts related to interventional radiology. The reliability of the survey instrument was judged for internal consistency at the completion of the web based survey using a Cronbach alpha of 0.7 or greater as an acceptable value for reliability. The Cronbach alpha was scored at 0.731 for internal

consistency for “knowledge of radiation practices” and .926 for internal consistency for “compliance with radiation safety practices”, thus the instrument was deemed reliable.

Population

The survey invitation postcards were mailed to all 300 ARRT certified interventional technologists residing in Ohio and holding an Ohio Radiography License. Contact information for these technologists was obtained from the American Registry of Radiologic Technologists. The Ohio Department of Health state licensing information was cross-referenced with the ARRT list of Ohio technologists certified in cardiac interventional radiography and/or vascular interventional radiography to ensure they were employed in Ohio. All duplicate entries were removed to maintain the integrity of the population.

Data Analysis

Descriptive parameters, including frequencies are reported for all questionnaire items. The relationship the two dependent constructs (self-reported knowledge of radiation safety practices and compliance with radiation safety practices) and the three independent variables (level of initial radiography education obtained; years in professional practice; and type of work site) will be analyzed utilizing Spearman Rho and Pearson Product correlation coefficients. The construct of self-reported knowledge of radiation safety practices is a combination of responses to questions 9, 12, 16, 24, and 25. The construct of compliance is measured by a combination of responses to questions 10, 11, 14, 17, 18, 20, 21, 22, 23, 26, 27, 28, 29, 30, and 31.

Chapter 3

Results

Response rate

Survey invitation postcards were mailed to 300 registered radiologic technologists in the state of Ohio who met the qualifications of holding ARRT certification in radiography with an advanced certification in (CI), (VI), or (CV). The initial postcards were mailed on September 15, 2012 and follow-up postcards were mailed on October 2, 2012. The survey was closed for analysis on October 15, 2012. A total of 60 technologists responded from the population surveyed resulting in a 20% response rate.

Demographics

Of these 60 respondents, 70% (n=42) of respondents had worked as a radiologic technologist for over 20 years, 10% (n=6) had worked for 16-20 years, 6.7% (n=4) had worked for 11-15 years, 6.7% (n=4) had worked for 6-10 years, and 6.7% (n=4) had worked for 1-5 years. None of the technologists responding to the survey had been a radiologic technologist for less than 1 year.

In reference to ARRT certification in Radiography, 67% (n=40) of the respondents had been ARRT certified in Radiography for over 20 years, 11.7% (n=7) had been certified for 16-20 years, 8.3% (n=5) had been certified for 11-15 years, 8.3% (n=5) had been certified for 6-10 years, and 5% (n=3) had been certified for 1-5 years. The number of years individuals had been ARRT certified in Cardiovascular/Interventional Radiology varied considerably. The majority of respondents have been ARRT certified 16-20 years, 26.7% (n=16). Furthermore, 23.3% (n=14) of surveyed technologists held certification in Cardiovascular/Interventional Radiology for 1-5 years, 21.7% (n=13) held certification for 21+ years, 20% (n=12) held certification for 11-15

years, 5% (n=3) held certification for 6-10 years, and 3.3% (n=2) held certification for less than one year.

Table 1

	<1 year		1-5 years		6-10 years		11-15 years		16-20 years		21+ years	
	n	%	n	%	n	%	n	%	n	%	n	%
How many years have you worked as a Radiologic Technologist?	0	0	4	6.7	4	6.7	4	6.7	6	10	4	70
How many years have you been ARRT certified in Radiography?	0	0	3	5	5	8.3	5	8.3	7	11.7	4	66.7
How many years have you been ARRT certified in Cardiovascular/Interventional radiography?	2	3.3	1	23	3	5	1	20	1	26.7	1	21.7

Forty-four respondents (73.3%) were currently employed in cardiac or vascular interventional radiology in the state of Ohio at the time of the survey. The 16 respondents (26.7%) who were not currently employed in cardiac or vascular interventional radiology in Ohio at the time of the survey were directed to the end of the survey and were not asked any further questions. Of the 44 technologists who are currently employed in cardiac or vascular interventional radiology, 43 responded to the questions regarding gender and age. Seventy percent (n=30) of the population surveyed were female, and 30.2% (n=13) were male (Table 2). The most frequent age range was over 45 years old (69.8%, n=30), followed by 16.3% (n=7) being 26-35 years old, and 14.0% (n=6) being 36-45 years old. No technologist surveyed responded as being less than 25 years of age (Table 3).

Table 2

Gender	n	%
Male	13	30.2
Female	30	69.8

Table 3

Age	n	%
<20 yrs	0	0.0
20-25 yrs	0	0.0
26-35 yrs	7	16.3
36-45 yrs	6	14.0
46+ yrs	30	69.8

Education and Training

The majority of the respondents, 45.5% (n = 20), identified adult vascular interventional radiology as her/his primary area of practice. Thirteen technologists (29.5%) worked primarily in adult cardiac interventional radiology and 11 (25.0%) worked in adult cardiac and vascular interventional radiology. None of the technologists responding to this survey were primarily employed in a pediatric area (Chart 1). The majority of respondents, 54.5%, worked in a hospital with 300 or more beds (n=24), followed by employment in hospitals with 100-299 beds (31.8%, n=14), and in hospitals with less than 100 beds (6.8%, n=3). Two respondents reported employment in an outpatient center and one technologist was employed as a clinical education specialist. None of the respondents were employed in a physician's office or as a commercial vendor (Chart 2).

Chart 1

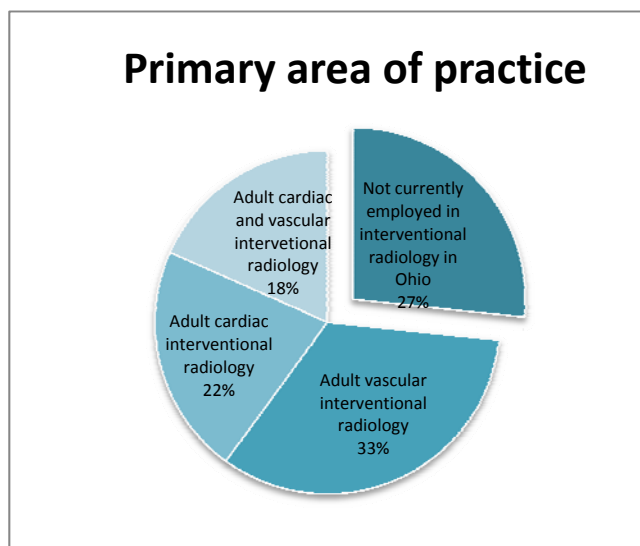
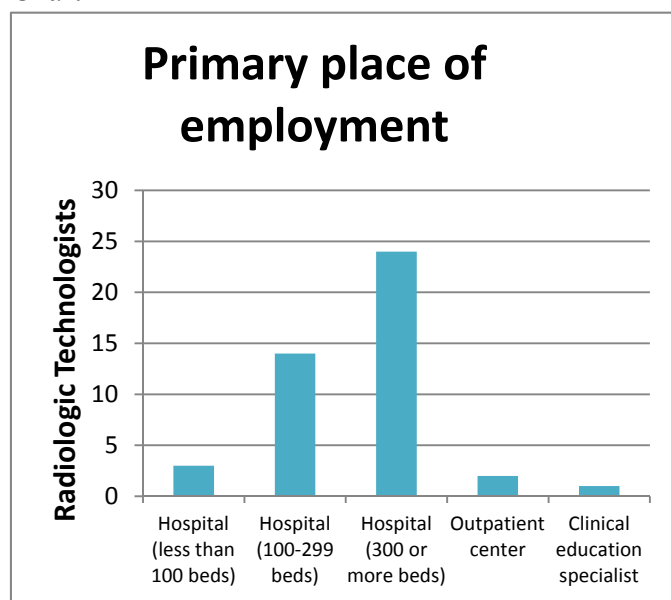


Chart 2



In terms of primary radiography education, 45.5% of the respondents are graduates of a hospital based programs and 45.5% of the respondents are graduates of a two-year associate degree program. Only three of the technologists reported initial education in a four-year bachelor degree program and one technologist was trained in a military program (Chart 3). Fifteen technologists reported completion of additional education, post radiography. Eleven reported earning an associate's degree; eight reported earning a Bachelor's degree and one respondent reported earning a Master's degree (Chart 4).

Chart 3

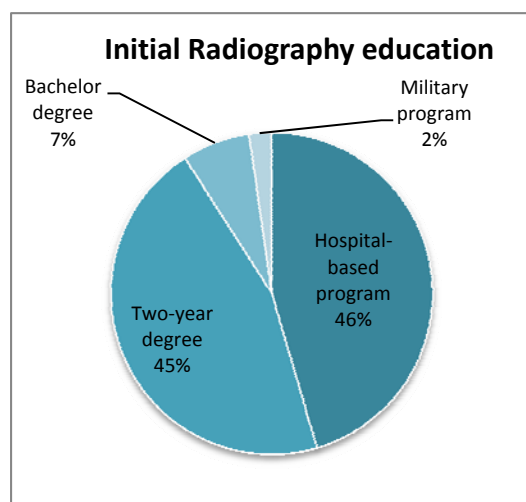
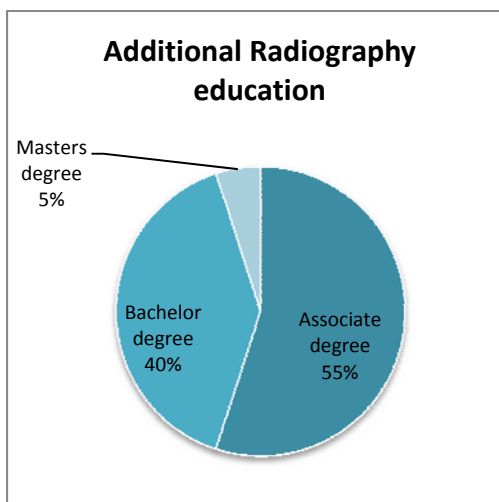


Chart 4



Of the 43 technologists who completed the entire survey, there were multiple types of continuing education activities reported including directed readings (65.1%, n=28), vendor sponsored activities (60.5%, n=26), on-line resources (46.5%, n=20), employer-sponsored seminars (39.5%, n=17), conferences (39.5%, n=17), and community college or university courses (9.3%, n=4) (Chart 5). There was a wide variety of continuing education topics reported by the 43 technologists including radiation physics, radiation safety, pharmacology, interventional techniques, interventional equipment, fluoroscopy, and pathology. Interventional techniques were the most commonly cited topic of continuing education (83.7%), followed by radiation safety (65.1%) and interventional equipment (65.1%). Pathology (55.8%), fluoroscopy (41.9%), pharmacology (25.6%), and radiation physics (23.3%) were also reported as continuing education topics (Chart 6).

Chart 5

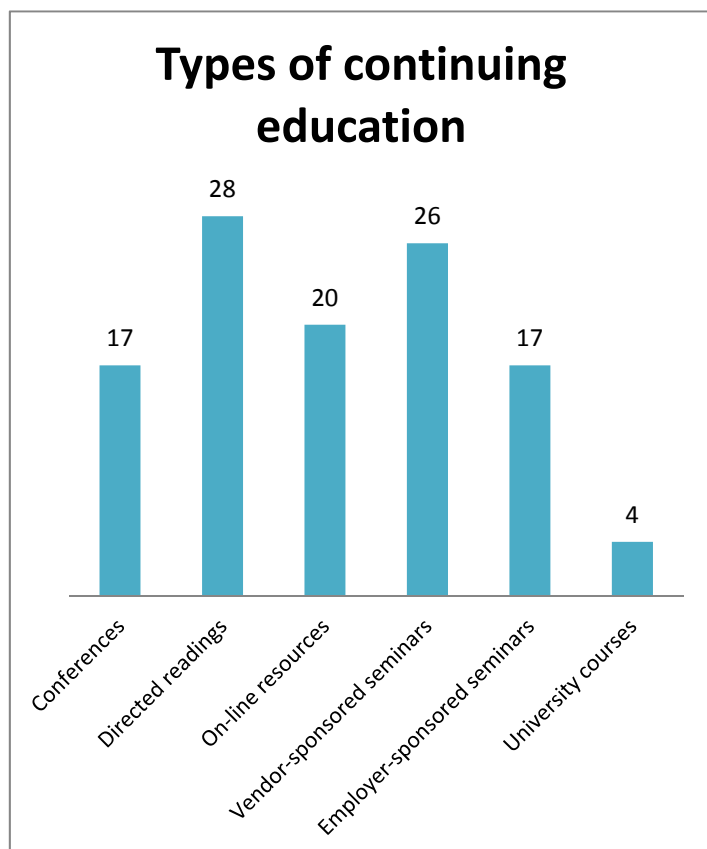
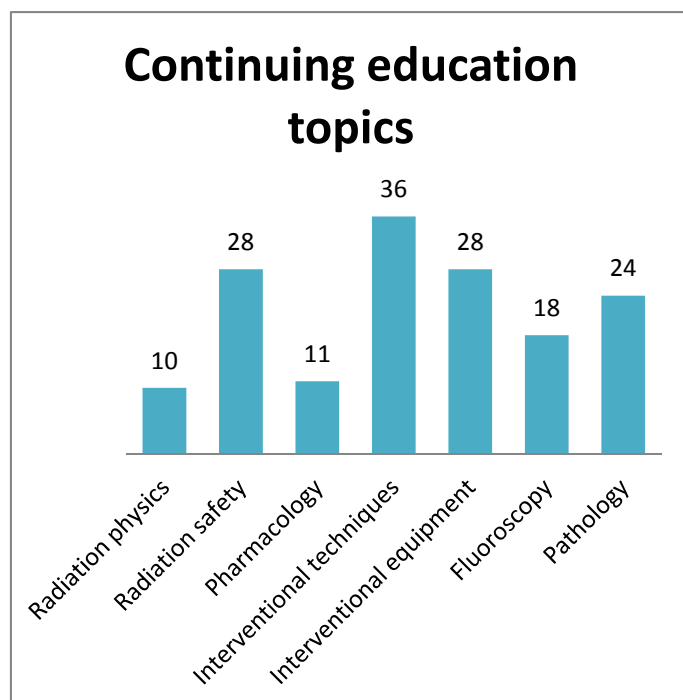


Chart 6



Surprisingly, only eight of the technologists responding to the survey were aware of the Image Wisely campaign. Thirty-one technologists (72.1%) reported that their place of employment has an established follow-up protocol for patients who have received radiation exposure above a set threshold, six (14.0%) reported no such policy was in place at their site, and 6 (14.0%) were unsure if her/his institution had such a policy. Forty-two of the 43 technologists responded that they attended patient and personnel radiation safety and protection training or education at their place of employment.

Table 4

	Yes	No	Unsure
Aware of Image Wisely	8	35	---
Place of employment has follow-up protocol for excess radiation exposure	31	6	6
Staff attend patient and personnel radiation safety training and/or education	42	1	---

1. What is the frequency with which interventional technologists comply with radiation safety practices?

Personnel Radiation Protection

Half of the respondents chose “lead body aprons” as the best method of protecting themselves from whole body occupational radiation exposure and the other 50% chose “keeping at least 6 feet away from the patient” as the best method for protecting themselves from whole body radiation exposure. The majority (74.4%) reported wearing a wraparound apron and the remaining 25.6% reported wearing a front-only apron (Chart 6). Approximately 65% of technologists responding to the survey reported wearing one dosimeter during fluoroscopic procedures. Fifteen (34.9%) reported wearing a second dosimeter and no technologist reported he/she did not wear a dosimeter. Nine technologists (20.9%) reported also wearing a TLD eye (n=5) or ring (n=4) dosimeter (Chart 7). In terms of the location of the whole body dosimeter, 69.8% (n=30) wear the dosimeter at the level of the thyroid above a lead apron, 19% (n=8) wear the dosimeter under a lead apron at a level other than the thyroid, and 9.5% (n=4) wear the dosimeter under a lead apron at the level of the thyroid (Chart 8).

Chart 6

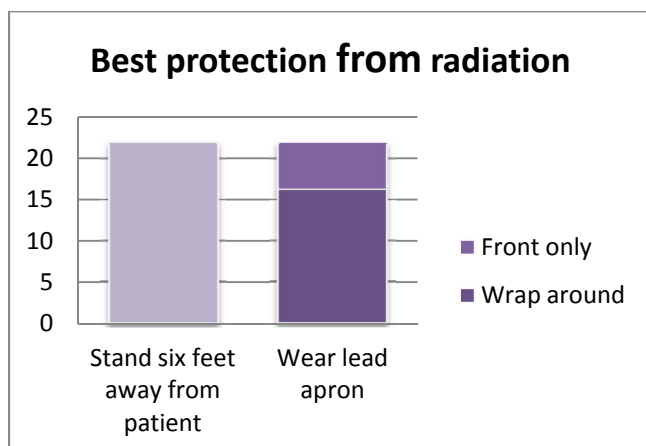


Chart 7

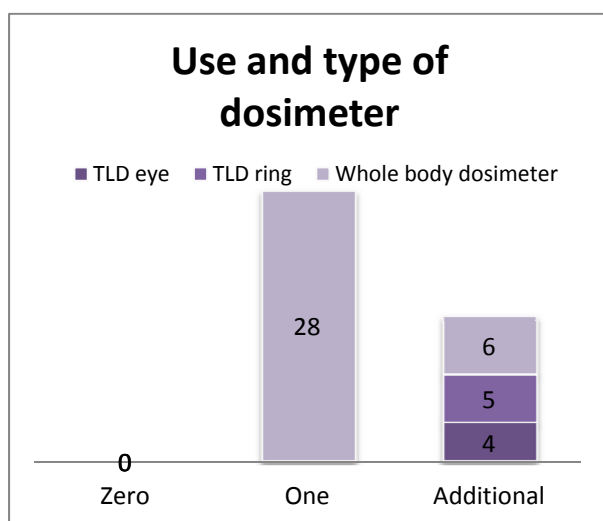
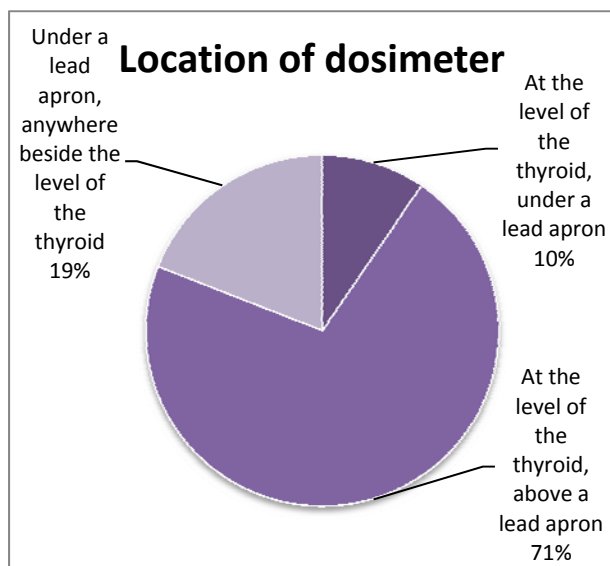


Chart 8



Thirty-six technologists reported that their hands were “rarely” in the path of the beam, six respondents reported that their hands were “sometimes” in the path of the beam, and only one technologist reported that her/his hands were “frequently” in the path of the beam. When asked how frequently the technologist would wear leaded gloves, the majority (90.7%) indicated they never wore leaded gloves. Only four technologists reported they sometimes used lead gloves as a method of personnel protection. However, all of the technologists responding to this survey reported they routinely wear a lead body apron. Thirty-five of the 43 technologists responded they always wear a thyroid shield, four technologists indicated they sometimes wear a thyroid collar, and four responded they never wear a thyroid collar for radiation protection. In terms of radiation protection of the eyes, the majority of technologists reported that they never wear leaded glasses (60.5%, n=26). Eleven technologists (25.6%) indicated they “always” wear leaded glasses, and six (14%) said they “sometimes” wear leaded glasses.

Table 5

	Always/ Frequently		Sometimes		Never/ Rarely	
	n	%	n	%	n	%
Hands in the path of the beam	1	2.3	6	14	36	83.7
Use leaded gloves	0	0	4	9.3	39	90.7
Use a thyroid shield	35	81.4	4	9.3	4	9.3
Wear leaded glasses	11	25.6	6	14	26	60.5

Occupational dose varies during cardiac and vascular interventional procedures, dependent upon the distance and angle an individual stands from the x-ray beam. Thirty-two technologists (76.7%) reported that they stand to the side of an image receptor when a horizontal beam is in use; eight technologists stated that they stand behind the image receptor, and three

reported that they stand near the path of the beam. When a vertical beam is in use, 23 technologists stated they stand at the foot of the patient, 19 technologists report standing next to the patient's torso, and one technologist indicated he/she stands at the head of the patient.

Chart 9

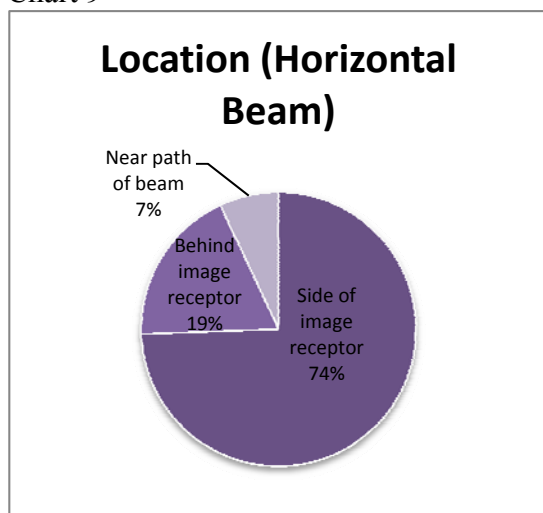
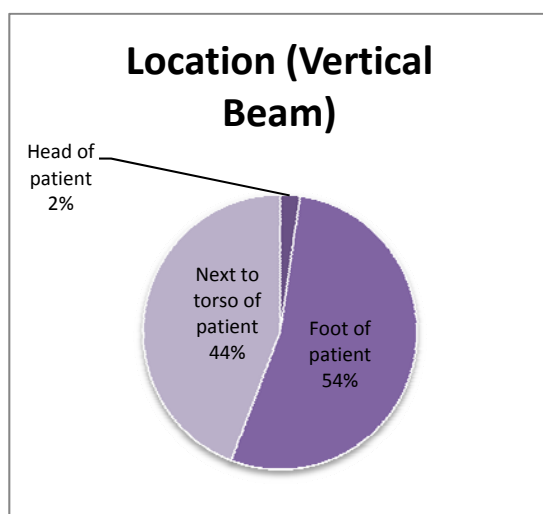


Chart 10



Patient Radiation Protection

Twenty-nine respondents (65.9%) said they have not told patients who are worried about radiation exposure that they will receive more radiation from the sun at the beach in one day than from their diagnostic x-rays and fifteen (34.1%) responded that they have used this analogy in

discussing radiation dose with their patients. Technologists responded that they decrease patient dose by using lead shielding for gonads (65.9%, n=29), using an x-ray tube filter (59.1%, n=26), adjusting mAs to patient size (54.5%, n=24), using lead shielding for other areas of the body (52.3%), and using lead shielding for the thyroid (36.4%, n=16) (Chart 11). Out of 43 technologists who completed the survey, 19 technologists (44.2%) reported they use both stationary and movable shields on patients, 14 (32.6%) reported they use only movable shields, 1 (2.3%) reported only using stationary shields, and 9 technologists (20.9%) said they do not use shields (Chart 12). When asked how to effectively to reduce patient dose by manipulating SID and OID, 17 technologists responded they would increase the SID and decrease the OID, 11 technologists responded they would decrease both the SID and OID, 7 technologists responded they would decrease the SID and increase the OID, and 2 technologists responded they increase both the SID and OID. Six technologists responding to the survey did not believe that manipulating the SID and OID was necessary in helping to reduce patient radiation dose (Chart 13).

Chart 11

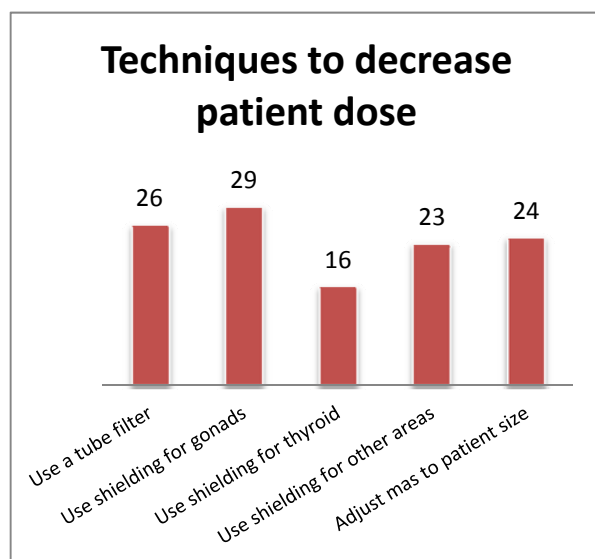


Chart 12

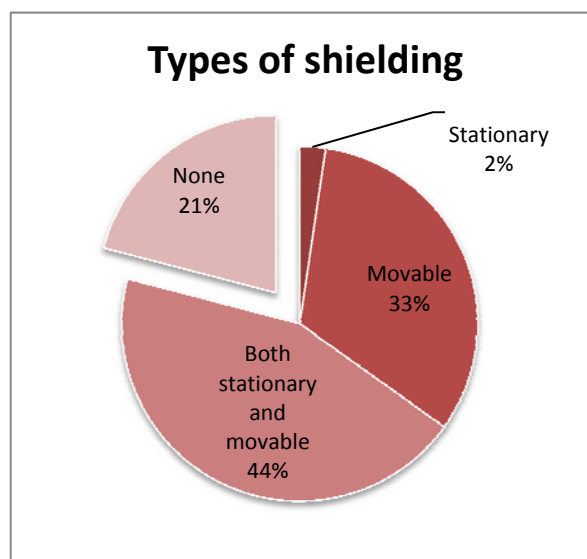
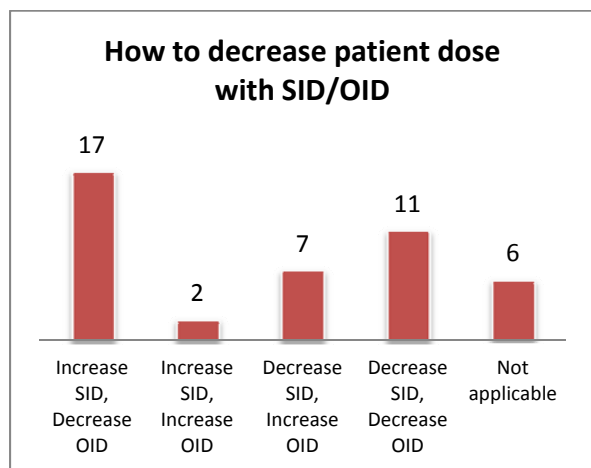


Chart 13



Forty four technologists responded to the majority of the questions in this section of the survey. Forty-one respondents (95.3%) reported placing the image intensifier as close to the patient as possible during a fluoroscopic procedure to reduce patient dose. One technologist responded that the distance/position of the image intensifier is not an issue in reducing patient dose and one technologist stated he/she does not position the image intensifier. When asked about the frequency of using a low or high frame rate, five technologists skipped the question (11.6%). The most frequent answer was a using a high frame rate 1-25% of the time (55.9%, n=19) and a low frame rate 76-100% of the time (45.9%, n=17) (Table 6).

Table 6

	0		1-25%		26-50%		51-75%		76-100%	
	n	%	n	%	n	%	n	%	n	%
Low rate	3	8.1	5	13.5	4	10.8	8	21.6	17	45.9
High rate	7	20.6	19	55.9	3	8.8	2	5.9	3	8.8

All but one of the respondents always ask female patients in their reproductive years about pregnancy status. Use of pulse fluoroscopy, image intensification zoom and last-image

hold also impact upon patient radiation dose. Over half of the respondents reported they always use pulse fluoroscopy. Eleven technologists reported the use of pulse fluoroscopy whenever possible and 8 technologists reported they never use the pulse option. Twenty-one technologists (48.8%) responded they rarely use the “zoom” option, only utilizing this feature when it is necessary. Nineteen technologists (44.2%) responded they sometimes use the zoom feature and three technologists reported frequent use of the zoom function. The majority of respondents (58.1%) reported that they always use last-image-hold to review images in place of live fluoroscopy or cine imaging. Sixteen technologists (37.2%) responded they sometimes use last-image-hold and two technologists responded they never use this function. When asked whether the technologist overlaps fields when imaging a procedure, 23.3% responded they always use this function, 58.1% responded they sometimes overlap fields, and 18.6% responded they never overlap the fields. The last issue addressed regarding patient radiation dose reduction was related to the use of collimation as a method restricting the x-ray beam. All of the technologists responding to the survey indicate they use collimation, however only 76.7% of the technologists reported they always collimate to the area of interest. (Table 7)

Table 7

	Always/ Frequently		Sometimes		Never/ Rarely	
	n	%	n	%	n	%
Ask pregnancy status	43	97.7	1	2.3	0	0.0
Use pulse fluoroscopy	24	55.8	11	25.6	8	18.6
Use zoom option	3	7.0	19	44.2	21	48.8
Use "last-image-hold" to review images	25	58.1	16	37.2	2	4.7
Overlap fields when imaging	10	23.3	25	58.1	8	18.6
Collimate to field of interest	33	76.7	10	23.3	0	0.0

2. What is the relationship the self-reported knowledge of radiation safety practices and the:

a. level of initial radiography education obtained;

There was not a significant correlational trend between the level of initial radiography education obtained and the self-reported knowledge of radiation safety practices. There was one statistically significant weak correlation (.345; $p = .017$) between the level of initial education and the technologist's knowledge of standing six feet away from the radiation source to reduce radiation exposure. However, this result is limited because of the few number of respondents reporting initial radiography education at the baccalaureate level. No other relationship was significant at the $p < .05$ level. Correlation coefficients and significance levels are reported in Table 8.

Table 8

Question 2a: Knowledge of radiation safety practices and level of initial education		
	Correlation Coefficient	Significance
Q9: Stand at least 6 feet away from the source to reduce radiation dose	0.345	0.017*
Q12: Techniques to reduce patient dose	-0.240	0.117
Q16: Place II as close to the patient as possible	0.125	0.389
Q19: Maximize SID and reduce OID	-0.120	0.407
Q24: Stand behind the II when horizontal beam is in use	-0.208	0.151
Q25: Stand at the patient's feet when a vertical beam is in use	0.210	0.147

n=44, * = significant at $< .05$

b. years in professional practice; and

There was not a strong overall relationship between the years in professional practice and the self-reported knowledge of radiation safety practices. However, two significant relationships

were identified. Two significant correlations were identified in this category between the dependent construct “number of years in professional practice” and knowledge of how to manipulate the OID and SID to reduce patient dose and obtain diagnostic images (.380; $p=.008$) and where the technologist stands when using a horizontal x-ray beam (.449; $p=.002$). However, it should be noted that both were fairly weak positive relationships. No other variables resulted in a significant relationship at the $p<.05$ level. Correlation coefficients and significance levels are reported in Table 9.

Table 9

Question 2b: Knowledge of radiation safety practices and years in professional practice		
	Correlation Coefficient	Significance
Q9: Stand at least 6 feet away from the source to reduce radiation dose	0.006	0.966
Q12: Techniques to reduce patient dose	-0.078	0.613
Q16: Place II as close to the patient as possible	0.138	0.339
Q19: Maximize SID and reduce OID	0.380	0.008*
Q24: Stand behind the II when horizontal beam is in use	0.449	0.002*
Q25: Stand at the patient's feet when a vertical beam is in use	0.047	0.743

n=44, * = significant at $<.05$

c. type of work site

There was a significant overall relationship in reference to the type of worksite and the self-reported knowledge of radiation safety practices suggesting that technologists employed in a larger work site were knowledgeable of the best radiation safety practices.

All six questions that dealt with knowledge of radiation safety practices yielded significant results. Strong, significant positive correlations were identified between the type of worksite and three radiation safety practices: the best method of protecting their body from whole body radiation; (.737; $p\leq 0.0001$); the knowledge of manipulating SID and OID (.598; $p\leq 0.0001$); and

knowledge of where to stand for the greatest radiation protection when using a vertical x-ray beam (.721; $p \leq 0.0001$). Statistical analysis resulted in identification of two relatively weak positive correlations between the type of work site and two additional radiation safety practices: knowledge of how to position the image intensifier to reduce patient and personnel dose (.378; $p=0.009$) and the knowledge of where to stand for the greatest radiation protection when using a horizontal x-ray beam (.357; $p= 0.014$). Interestingly, a significant weak, negative correlation was identified between the knowledge of how to reduce the patient's dose and the type of work site (-0.376; $p=0.011$) suggesting that technologist employed at a smaller work site were more knowledgeable regarding patient dose reduction. Correlation coefficients and significance levels are reported in Table 10.

Table 10

Question 2c: Knowledge of radiation safety practices and type of work site		
	Correlation Coefficient	Significance
Q9: Stand at least 6 feet away from the source to reduce radiation dose	0.737	0.000*
Q12: Techniques to reduce patient dose	-0.376	0.011*
Q16: Place II as close to the patient as possible	0.378	0.009*
Q19: Maximize SID and reduce OID	0.598	0.000*
Q24: Stand behind the II when horizontal beam is in use	0.357	0.014*
Q25: Stand at the patient's feet when a vertical beam is in use	0.721	0.000*

n=44, * = significant at $<.05$

3. What is the relationship the self-reported compliance with radiation safety practices and the:

a. level of initial radiography education obtained;

There was not a significant overall relationship between the level of initial radiography education obtained and the self-reported compliance with radiation safety practices. No question

yielded a significant relationship at the $p < .05$ level. Correlation coefficients and significance levels are reported in Table 11.

Table 11

Question 3c: Compliance with radiation safety practices and type of work site		
	Correlation Coefficient	Significance
Q10: Always ask females in their reproductive years if they are pregnant	0.089	0.539
Q11: Have not ever told a patient who is nervous about radiation they receive more radiation from the sun at the beach than from their diagnostic x-rays	0.582	0.000*
Q14: Body dosimeter at the level of the thyroid outside of the apron	0.582	0.000*
Q17: Always use pulse fluoroscopy	0.687	0.000*
Q18: Use a low frame rate 76-100% of the time, and a high frame rate 0-25% of the time	0.721	0.000*
Q20: Rarely use the zoom option	0.665	0.000*
Q21: Always use "last-image-hold" to review images versus live fluoroscopy	0.642	0.000*
Q22: Never overlap fields when imaging a procedure	0.410	0.005*
Q23: Always collimate to the area of interest	0.550	0.001*
Q26: use stationary and movable shields on the patient	0.794	0.000*
Q27: Hands in the path of the beam rarely	0.464	0.001*
Q28: Always use lead gloves when hands are in the beam	0.000	1.000
Q29: Wear wrap-around lead apron	0.530	0.000*
Q30: Always use a thyroid shield	0.474	0.001*
Q31: Always use leaded glasses	0.523	0.000*

n=44, * = significant at $< .05$

b. years in professional practice; and

A significant overall trend between the years in professional practices and the self-reported compliance with radiation safety practices was not evident. However a significant correlation was identified between three questions regarding compliance. **There was a strong, significant positive relationship between the number of years in professional practice and the technologists who always wear leaded glasses (.626; $p=0.000$). Two additional**

significant positive relationships, although weakly correlated, were demonstrated between the years in professional practice and the correct practice of using high and low frame rates (.341; $p=0.018$) and between the number of years in professional practice and the infrequent use of the zoom option (.297; $p=0.039$). No other correlation resulted in a significant relationship at the $p<.05$ level. Correlation coefficients and significance levels are reported in Table 12.

Table 12

Question 3b: Compliance with radiation safety practices and years in professional practice		
	Correlation Coefficient	Significance
Q10: Always ask females in their reproductive years if they are pregnant	0.096	0.504
Q11: Have not ever told a patient who is nervous about radiationo they receive more radiation from the sun at the beach than from their diagnostic x-rays	0.218	0.130
Q14: Body dosimeter at the level of the thyroid outside of the apron	-0.015	0.916
Q17: Always use pulse fluoroscopy	0.130	0.368
Q18: Use a low frame rate 76-100% of the time, and a high frame rate 0-25% of the time	0.341	0.018*
Q20: Rarely use the zoom option	0.297	0.039*
Q21: Always use "last-image-hold" to review images versus live fluoroscopy	0.220	0.165
Q22: Never overlap fields when imaging a procedure	0.276	0.055
Q23: Always collimate to the area of interest	0.058	0.684
Q26: use stationary and movable shields on the patient	0.271	0.059
Q27: Hands in the path of the beam rarely	-0.182	0.206
Q28: Always use lead gloves when hands are in the beam	0.000	1.000
Q29: Wear wrap-around lead apron	0.214	0.138
Q30: Always use a thyroid shield	0.098	0.495
Q31: Always use leaded glasses	0.626	0.000*

n=44, * = significant at $<.05$

c. type of work site

There was a significant overall relationship between the type of worksite and the self-reported compliance with radiation safety practices.

Many significant positive relationships were identified regarding patient radiation safety. A significant positive strong correlation was identified between the correct compliance of not comparing radiation dose from the sun to radiation dose from diagnostic x-rays (.582; $p \leq 0.0001$). In terms of properly utilizing protective equipment to reduce patient radiation dose, significant positive strong correlations were identified between the type of work site and the use of both stationary and movable patient shields (.794; $p \leq 0.0001$); the correct use of pulsed fluoroscopy (.687; $p \leq 0.0001$); and the correct use of tight collimation limiting the x-ray beam to the area of interest (.550; $p=0.001$). Additionally, positive strong correlations were demonstrated in terms of the correct use of imaging options and the type of worksite including the correct use of high and low frame rates (.721; $p \leq 0.0001$); the correct use of the zoom option (.665; $p \leq 0.0001$); and the correct use of the last-image-hold option (.642; $p \leq 0.0001$). A significant weak correlation was demonstrated in the infrequent practice of overlapping fields when imaging (.410; $p=0.005$).

In reference to personnel safety, a strong significant positive correlation was demonstrated between the correct placement of a whole body dosimeter and the type of work site (.582; $p \leq 0.0001$). The analysis also yielded weak, significant positive relationships in reference to the type of work site and the use of protective personnel devices, including technologists infrequently placing their hands in the path of the primary x-ray beam (.464; $p=0.001$); technologists wearing wraparound body aprons (.530; $p \leq 0.0001$); the use of thyroid shielding devices (.474; $p \leq 0.0001$); and technologists wearing leaded glasses (.523; $p \leq 0.0001$). The only question that did not yield a significant relationship dealt with the use of lead gloves, and no

technologist, regardless of work site, reported always wearing lead gloves. Correlation coefficients and significance levels are summarized in Table 13.

Table 13

Question 3c: Compliance with radiation safety practices and type of work site		
	Correlation Coefficient	Significance
Q10: Always ask females in their reproductive years if they are pregnant	0.089	0.539
Q11: Have not ever told a patient who is nervous about radiation they receive more radiation from the sun at the beach than from their diagnostic x-rays	0.582	0.000*
Q14: Body dosimeter at the level of the thyroid outside of the apron	0.582	0.000*
Q17: Always use pulse fluoroscopy	0.687	0.000*
Q18: Use a low frame rate 76-100% of the time, and a high frame rate 0-25% of the time	0.721	0.000*
Q20: Rarely use the zoom option	0.665	0.000*
Q21: Always use "last-image-hold" to review images versus live fluoroscopy	0.642	0.000*
Q22: Never overlap fields when imaging a procedure	0.410	0.005*
Q23: Always collimate to the area of interest	0.550	0.001*
Q26: use stationary and movable shields on the patient	0.794	0.000*
Q27: Hands in the path of the beam rarely	0.464	0.001*
Q28: Always use lead gloves when hands are in the beam	0.000	1.000
Q29: Wear wrap-around lead apron	0.530	0.000*
Q30: Always use a thyroid shield	0.474	0.001*
Q31: Always use leaded glasses	0.523	0.000*

n=44, * = significant at <.05

Discussion

The results of this survey demonstrate positive results from technologists working in cardiovascular- interventional radiology in relation to radiation safety. The majority of the technologists surveyed have been certified by the American Registry of Radiologic Technologists in both radiography and cardiac/vascular interventional radiology for over 21 years, and have been working in the field for 16-20 years. The majority of respondents were over

46 years old. These demographics show that the population attended their initial education over 21 years ago, and therefore rely on continuing education to stay current on radiation safety and best interventional practices. There was a wide variety of continuing education methods and topics identified by respondents; however directed readings and interventional practices, respectively, were the most common content area for continuing education. These continuing education methods, combined with the fact that all respondents identified as working in an adult setting, may explain why the majority of radiologic technologists surveyed were not aware with the Image Wisely campaign since it was initiated to focus on pediatric radiation exposure. All except one radiologic technologist responded that their hospital provided training regarding patient and personnel radiation safety, which is reassuring. In addition, almost 75% of respondents reported that their place of employment has a follow-up procedure for patients who receive radiation exposure beyond a set threshold.

Respondents to this survey demonstrated proficiency in protecting themselves against radiation. Half of the respondents use lead shields to best protect themselves against the harmful effects of radiation, and half stand at least 6 feet away from the patient to best protect themselves. However, all respondents replied that they wear a lead apron, with the majority wearing a wrap-around lead apron. The majority of interventional technologists also report that they always wear a thyroid shield. All radiologic technologists report wearing at least one dosimeter, and just over a quarter of respondents wear two or more dosimeters. The majority wear the dosimeter above a lead shield at the level of the thyroid, which is correct placement. When manipulating fluoroscopic interventional equipment, the majority of respondents stand in the correct position: at the side of the image receptor when a horizontal beam is in use, and at the foot of the patient when a vertical beam is in use. Unfortunately, nearly all interventional

technologists responded that they do not use lead gloves. When considering the high doses and fluoroscopic times associated with interventional procedures, combined with the sensitivity of the cornea, interventional technologists should be encouraged to wear leaded glasses at all times. Although most technologists responded that their hands are not frequently in the path of the beam, some technologists responded that their hands are in the path of the beam at times and, if possible, leaded gloves should be used in these situations. However, it is difficult to put on and take off lead gloves under sterile conditions which could explain the low positive response to this question.

The radiologic technologists responding to this survey also demonstrate proficiency when dealing with patient radiation safety. All technologists reported using collimation and over three quarters of the technologists said that they always use collimation when performing procedures. Collimation should be used by technologists to reduce patient dose, obtain better images, and reduce scatter radiation which will reduce their dose. Nearly all technologists responded that they asked female patients in their reproductive age pregnancy status. Over two thirds of the respondents know that they should not use the analogy of spending a day in the sun to educate patients of radiation doses. Although the majority of technologists said that they use movable or stationary shields on patients, there were still about 20% of technologists that do not use any type of shielding. Since fluoroscopic times can reach high levels in almost all interventional procedures, all technologists should advocate for the patient and protect them by using lead shields.

The results of this survey demonstrated mixed results regarding radiologic technologists' knowledge of equipment manipulation techniques to reduce radiation dose to the patient and to personnel. Results of the survey indicate that almost all technologists place the image intensifier

(II) as close to the patient as possible when imaging, which is correct practice. The majority of radiologic technologists surveyed also responded that they use zoom rarely, which will reduce radiation exposure. The use of the zoom function for magnification will increase dose to the patient. Furthermore, almost all technologists responded that they either use pulse fluoroscopy frequently or as often as possible. The use of pulse fluoroscopy greatly reduces radiation dose because instead of using a constant beam of radiation, the fluoroscopic tube is only activated for a set number of frames per second. Unfortunately, there were some areas where technologists were unsure of the best methods for reducing radiation dose. When asked the proper manner to manipulate SID and OID to produce an optimal image and reduce patient dose, less than half of technologists knew that it was ideal to increase the SID and decrease the OID. Although the correct answer was also the most common answer to this question, the fact that less than half of interventional technologists knew the proper manipulation of distances is disappointing. Furthermore, just over half of the technologists report using last image hold to review images. All interventional technologists should be using last image hold to review images instead of live fluoroscopy. Finally, the survey showed that interventional technologists are not properly educated on the use of high and low frame rates to reduce patient dose. When asked how frequently he/she utilizes a high and low frame rate, eight technologists skipped the entire question. However, the majority of technologists who did complete the question answered as using a low frame rate 76-100% of the time, and a high frame rate 1-25% of the time. A low frame rate will result in the lowest radiation dose, yet some circumstances do require a high frame rate.

The correlation results suggested that there was no overall relationship between the level of initial education and the knowledge of radiation safety practices. There was only one question

regarding knowledge of how to reduce radiation exposure by standing at least six feet away from the radiation source. However, this data could be skewed due to the low number of technologists who responded with obtained a Bachelors' degree or a military degree. Furthermore, this relationship was weakly correlated. There was also not an overall relationship between the number of years in professional practice and the knowledge of radiation safety practices. Two questions had significant results in this category, which dealt with how to manipulate OID and SID, and where to stand when a horizontal beam is in use. The weak, positive correlations suggest that it is possible that as a technologist has more years in practice, he or she will become more knowledgeable in certain areas of radiation safety practices.

The survey did show that there was an overall significant relationship between the knowledge of radiation safety practices and the type of work site. Every question that dealt with knowledge of radiation safety practices and the type of work site showed to have a significant relationship. Interestingly, there was a weak, negative correlation between knowledge of techniques used to reduce patient dose and the type of work site, which suggests that technologists at smaller hospitals and sites could be more knowledgeable on these techniques. Other questions regarding standing six feet away from the source to reduce radiation dose, maximizing SID and reducing OID, and where to stand when the vertical beam is in use all had strong, positive correlations that suggested the knowledge of these practices increases as the size of the work site increases. This could be due to the type of training installed in a larger hospital setting or more formal orientation processes at larger institutions.

The survey did not show an overall relationship between the level of initial education and compliance with radiation safety practices. This suggests that the level of education does not affect how compliant a technologist is with the radiation safety practices in place. The survey

also did not show an overall relationship between the number of years in professional practice and the compliance with radiation safety practices. However, there were significant relationships, though with weak, positive correlations, between compliance with the correct practice of using high and low frame rates to decrease patient dose and how frequently the technologist uses the zoom option when imaging. It is possible the areas that deal with equipment manipulation (high and low frame rate, zoom option) could increase in compliance as years increase due to more experience with the specific equipment and becoming more comfortable in adjusting these settings. There was a strong, positive correlation between the number of years in professional practice and the use of leaded glasses. This increase in compliance with wearing leaded glasses could be due to technologists becoming more aware of the deterministic effects of radiation as they age.

The survey showed a strong overall relationship between the type of work site and compliance with radiation safety practices. Every question regarding compliance with radiation safety practices and type of work site yielded a significant relationship with the exception of one. There was not a significant relationship between technologists who always ask females in their reproductive years if they could be pregnant. This suggests that the type of work site does not affect if a technologist asks pregnancy status. In addition to this, every question had a positive correlation, which suggests that the compliance with radiation safety practices increases as hospital size increases. This fact could be due to more regulation of larger institutions and an increased awareness of accreditation agencies. Further, a larger institution would employ more technologists than a smaller institution, so there could be more opportunities for technologists to learn from other technologists.

Interpretation in Context of Literature

Unlike the surveys completed by Slechta and Raegan (2008) and Raegan and Slechta (2010), interventional radiology technologists in Ohio were found to be compliant with knowledge of radiation safety techniques and protocols. The population surveyed was similar to the populations surveyed in California by Slechta and Raegan (2008) and Raegan and Slechta (2010) in that the most common type of education was an associate's degree, the most common place of employment was a hospital, and the majority of participants have been practicing technologists for more than sixteen years. However, the results from the study conducted by Slechta and Raegan (2008) suggested that radiologic technologists demonstrated poor compliance with radiation safety procedures, particularly in regards to personnel compliance. In contrast, the results from this interventional radiology survey differ from these results. The most current survey showed high compliance with personnel and patient radiation safety. Since similar populations were surveyed, it is possible the most current survey showed higher compliance because interventional radiology procedures have higher fluoroscopic times and radiation doses, so staff are more aware of techniques and procedures taken to reduce dose to self and dose to patient. It is also possible that technologists are more compliant with radiation safety due to their place of employment providing training for staff.

Although the population surveyed in this research study focused on interventional radiologic technologists and the population surveyed by Sanchez et al. (2012) focused on interventional radiologists, noticeable similarities and differences can be seen between the two studies. Unlike the radiologists surveyed by Sanchez et al (2012), all technologists reported wearing both a dosimeter and a lead apron. However, in both studies, wearing more than one dosimeter was not common practice despite recommendations by the International Commission on Radiological Protection. Both studies also showed that attention to the harmful effects of

radiation to the lens of the eye may not be taken as seriously as it should, due to the lack of eye lens dosimeters in the survey by Sanchez et al (2012) and the lack of technologists who reported wearing leaded glasses in this survey. Both surveys demonstrate the need for continued awareness of radiation safety practices among technologists and physicians.

Limitations

With a self-reporting survey such as the one that was used in this research study, there is always the potential for reporting bias. Additionally, the low response rate also limits the statistical power affecting the ability of this study to accurately portray the entire population. Since the survey instrument was web-based, there is the risk that the sampling bias may be present in terms of technologists who did not have access to a computer to complete the survey. Lastly, the survey was only offered to technologists who are registered with the American Registry of Radiologic Technologists in (CV), (CI), or (VI), therefore results can only be generalized to this population, thus it may not represent every technologist who is currently working in an interventional suite in the state of Ohio. It is not state or national law for a technologist to hold a post-primary certification to work in an interventional radiology department, and there are technologists who are currently employed in interventional suites who do not hold one of these credentials but were not contacted to complete the survey.

Conclusions and Implications for Further Research

In conclusion, a limited survey of interventional radiologic technologists in the state of Ohio demonstrated a satisfactory level of knowledge of compliance with radiation safety practices. Significant relationships were identified between the type of work site and the knowledge of radiation safety practices and compliance with the radiation safety practices. Interestingly, however, there was not a relationship found between neither the number of years in

professional practice nor the level of initial education in relation to the two dependent constructs. Future research could be carried out to investigate the knowledge of and compliance with radiation safety practices in relation to the three independent variables (level of initial education, years in professional practice, and type of work site) in a national survey to obtain a better understanding of the practices of interventional radiology technologists across the country. Furthermore, research regarding the acquired occupational health effects of medical radiation by interventional radiology technologists could be important for future radiation dose limits and workplace restrictions.

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Appendix A**Ohio Interventional Technologist Education and Practice Survey**

(All responses will be anonymous)

a. Professional Experience

1. How many years have you worked as a Radiologic Technologist?

☐ <1 yr

☐ 1-5 yrs

☐ 6-10 yrs

☐ 11-15 yrs

☐ 16-20 yrs

☐ 21+ yrs

2. How many years have you been ARRT certified in Radiography?

☐ <1 yr

☐ 1-5 yrs

☐ 6-10 yrs

☐ 11-15 yrs

☐ 16-20 yrs

☐ 21+ yrs

3. How many years have you been ARRT certified in Cardiovascular/Interventional Radiology?

☐ <1 yr

☐ 1-5 yrs

☐ 6-10 yrs

☐ 11-15 yrs

☐ 16-20 yrs

☐ 21+ yrs

4. Are you currently employed in cardiac or vascular interventional radiology in the state of Ohio?

☐ Yes

☐ No

5. What is your primary area of practice?

☐ Adult diagnostic radiography

☐ Pediatric diagnostic radiography

☐ Adult vascular and cardiac interventional radiology

☐ Pediatric vascular and cardiac interventional radiology

☐ Adult cardiac interventional radiology

☐ Pediatric cardiac interventional radiology

☐ Adult vascular interventional radiology

☐ Pediatric vascular interventional radiology

6. Primary place of employment

☐ Hospital (less than 100 beds)

☐ Hospital (100-299 beds)

☐ Hospital (more than 300 beds)

☐ Outpatient center

☐ Physician office

☐ Commercial vendor

☐ Other (please specify) _____

7. Initial Radiography education

☐ Hospital-based program

☐ 2-year degree (community college)

☐ Bachelors degree in Radiologic Technology/ Science

- ☐ Military program
- ☐ Other (please specify) _____

8. Additional education:

- ☐ Associates degree in _____
- ☐ Bachelor degree in _____
- ☐ Masters Degree In _____
- ☐ Other (please list) _____

B. General Radiation Protection

9. What is the best method of protecting yourself from whole body radiation exposure?

- ☐ Lead body aprons
- ☐ Keeping at least 6 feet from the patient
- ☐ Does not apply to my job

10. How often do you ask females that are in their reproductive years if they are pregnant?

- ☐ Always
- ☐ Sometimes
- ☐ Never

11. Have you ever told a patient who is nervous about their radiation exposure that they will receive more radiation from the sun at the beach in one day than from their diagnostic x-rays?

- ☐ Yes
- ☐ No

12. How do you decrease your patient's dose? (Check all that apply)

- ☐ Use an x-ray tube filter
- ☐ Adjust the mAs to patient size
- ☐ Use lead shielding for gonads
- ☐ Use lead shielding for thyroid

☐ Use lead shielding for other areas of body

C. Interventional Radiology

13. How many dosimeters do you wear during fluoroscopic procedures?

☐ I do not use a dosimeter

☐ One dosimeter

☐ Two or more dosimeters

14. Where do you wear your whole body dosimeter?

☐ I do not wear a dosimeter

☐ At the level of the thyroid under a lead apron

☐ At the level of the thyroid above a lead apron

☐ Under a lead apron, anywhere beside level of the thyroid

☐ Other _____

15. Do you wear any of the following additional dosimeters?

☐ TLD ring dosimeter

☐ TLD eye dosimeter

☐ Other _____

16. During a fluoroscopic procedure, with an under the table x-ray tube, where do you place the image intensifier (II)?

☐ as far away from the patient as possible

☐ as close to the patient as possible

☐ The distance/position does not matter

☐ I never position the image intensifier

17. How frequently do you use pulse fluoroscopy?

☐ Never

☐ Only when imaging procedures with children

☐ As much as possible

☐ Always

18. How often do you use a low or high frame rate when using pulse fluoroscopy?

	0%	1-25%	56-50%	51-75%	76-100%
Low	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
High	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

19. How do you manipulate the SID (source to image receptor distance) and OID (object to image receptor distance) to reduce patient dose and obtain diagnostic images?

☐ Increase the SID, Decrease the OID

☐ Increase the SID, Increase the OID

☐ Decrease the SID, Increase the OID

☐ Decrease the SID, decrease the OID

☐ Not applicable

20. How frequently do you use the “zoom” option?

☐ Frequently

☐ Sometimes

☐ Rarely / only when necessary

21. How frequently do you use “last-image-hold” to review images versus live fluoroscopy or cine?

☐ Always

☐ Sometimes

☐ Never

22. Do you overlap fields when imaging a procedure?

☐ Always

☐ Sometimes

☐ Never

23. How frequently do you collimate to the area of interest?

- ☐ Always
- ☐ Sometimes
- ☐ Never

24. Where do you stand when a horizontal x-ray beam is in use?

- ☐ To the side of the image receptor
- ☐ Behind the image receptor
- ☐ Near the path of the beam

25. Where do you stand when using a vertical x-ray beam?

- ☐ At the head of the patient
- ☐ At the foot of the patient
- ☐ Next to the patient's torso

26. Do you use stationary or movable shields on the patient?

- ☐ I do not use shields
- ☐ Stationary
- ☐ Movable
- ☐ Both stationary and movable

27. Are your hands in the path of the beam?

- ☐ Frequently
- ☐ Sometimes
- ☐ Rarely

28. Do you use leaded gloves?

- ☐ Always
- ☐ Sometimes
- ☐ Never

29. Do you wear a body lead apron?

☐ Yes, wrap around

☐ Yes, front only

☐ No

30. How frequently do you use a thyroid shield?

☐ Always

☐ Sometimes

☐ Never

31. How frequently do you wear leaded glasses?

☐ Always

☐ Sometimes

☐ Never

32. Does your place of employment have a follow-up protocol for patients who have received radiation exposure above a set threshold?

☐ Yes

☐ No

☐ Unsure

33. Did you undergo training or education at your place of employment regarding radiation safety and protections for yourself and your patients?

☐ Yes, Patient safety only

☐ Yes, Personnel safety only

☐ Yes, Both patient and personnel safety

☐ No

E. Demographics

34. What types of professional continuing education activities did you participate in within the past 24 months?

- ☐ Conferences
- ☐ On-line resources
- ☐ Directed readings
- ☐ Employer-sponsored seminars
- ☐ Vendor-sponsored seminars
- ☐ Community college or University courses

35. What professional continuing education topics did you review within the past 24 months?
(Check all that apply)

- ☐ Radiation physics
- ☐ Radiation safety
- ☐ Interventional techniques
- ☐ Interventional equipment
- ☐ Pharmacology
- ☐ Pathology
- ☐ Fluoroscopy

36. Are you aware of the Image Wisely campaign?

- ☐ Yes
- ☐ No

37. Gender

- ☐ Male
- ☐ Female

38. Age

- ☐ Less than 20 years
- ☐ 20-25 years
- ☐ 26-35 years

☐ 36-45 years

☐ 46 years or more

Thank you!

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